A TOTAL ECLIPSE OF THE SUN.*

By Robert G. Aitken.

The first lecture of the present course gave a general account of our solar system as a whole, emphasizing particularly the harmonies in the motions of its component bodies and its isolation from other stellar systems. The second lecture described in detail what we know about one special class of objects within our system—the comets. It has seemed to me appropriate that our third lecture should be devoted to the Sun itself, the most important object in the universe for us—the source of heat, light, mechanical and electrical power, and, in the material sense, of life itself, on our little globe.

But the phenomena of the Sun as revealed by our modern studies are so multifarious and raise so many intricate and interesting problems that it is quite impossible to treat them all in a single lecture. It is necessary to select, and I have chosen to place the emphasis in what I shall say this evening upon those phenomena which are more or less directly associated with a total eclipse of the Sun.

There are special reasons for this choice: No other natural phenomenon is so impressive, so startling, so fascinating, as a total eclipse of the Sun; many important advances in our knowledge of the Sun have had their origin in eclipse observations; the present year is a year of eclipses—seven, the maximum possible number, occurring within it; a total eclipse of the Sun will be visible in the western part of this country next year—June 8, 1918—for the first time in twenty-nine years; and, finally—a point of particular interest to us who are gathered here—our Society, the Astronomical Society of the Pacific, may be said to owe its existence to a total eclipse of the Sun. This was the eclipse of January 1, 1889, which, beginning at sunrise in the North Pacific Ocean, entered California near Point Arena at about 1:45 P. M., and swept across the State northeastwardly in a path some eighty miles broad, to end at sunset in northeastern Canada.

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The Lick Observatory which had begun active work only six months earlier, sent a party headed by the late Professor Keeler to a favorable situation on the central line of the shadow path. Nearby were expeditions from other American observatories, and a strong party from the Amateur Photographic Association of the Pacific Coast, under the energetic leadership of Mr. Charles Burckhalter of the Chabot Observatory. This party of amateurs secured many very successful photographs, which were later discussed by Professor Holden, and the results published in Volume I of the Lick Observatory Contributions. It was the cordial coöperation of amateur and professional observers on this occasion, and the interest in astronomy revealed and stimulated by it among our people, that led to the formation of our Society.

The questions which I think you would like to have me discuss in this lecture are: (1) What causes an eclipse of the Sun or of the Moon, and why do we so seldom see a total eclipse of the Sun? (2) What do astronomers hope to discover at the time of a total eclipse that they cannot find out by studying the Sun at other times? (3) Just what do they do to get ready for an eclipse and during the few minutes of its duration?

It does not require a vivid imagination to picture the terror inspired among primitive peoples by a solar eclipse. To see the Sun in midday slowly but surely disappear without apparent cause, is sufficiently awe-inspiring even to those who understand the reason and who have made special preparations to observe the phenomenon; and it is easy enough to see how such myths as that of the dragon devouring the Sun came into being. Even in quite modern times an eclipse of the Sun was seriously regarded as a portent, "a sign and a wonder in heaven," and there is a quaint story concerning a total eclipse which occurred in our own colonial days while the General Assembly of Connecticut was in session. Many members were alarmed, some exclaimed that the Judgment Day was at hand, but one sturdy member called for candles, that they might proceed with their business and be found doing their duty.

Long before the dawn of recorded history, however, far-seeing men like the Babylonian and Chaldean watchers of the skies had learned to associate eclipses of the Sun and of the Moon with the motions of these bodies relatively to the Earth, and had indeed discovered an approximate method of forecasting eclipse by means of an eclipse cycle, for which we still use the name they gave—the *Saros*.

It is obvious that all the planets and satellites in our system, since they shine merely by reflected sunlight, must constantly be attended by shadows sweeping thru space on the side turned away from the Sun, and that these shadows must be conical in shape (since the bodies casting them are approximately spheres), with bases equal to the cross-sections of the bodies intercepting the Sun's light, and lengths depending upon the sizes and distances of these bodies from the Sun. Every night we walk in the Earth's shadow, and, from a mountain height, like that of Mount Hamilton, or from the deck of a ship far out at sea, we can watch that shadow sweeping up the eastern sky as the Sun sinks farther and farther below the western horizon.

A beautiful example of such a shadow is that afforded by the passage of one of *Jupiter's* larger satellites across the planet's disk. The shadow can be seen by our telescopes only when it falls upon the planet, and then it appears as a nearly round black dot which travels across the bright planet from west to east. If we were on Jupiter within that shadow-spot, the Sun would be eclipsed for us.

Since the Moon revolves about the Earth from west to east once every month, it must be in conjunction (pass between the Earth and Sun) once each month—at new moon—and half a month later at full moon, be in opposition—on the opposite side of the Earth from the Sun. If the Moon's orbit were precisely in the same plane as that of the Earth, that is, if the Moon's apparent path among the stars were precisely the same as that of the Sun, there would be an eclipse of the Sun at every new moon and one of the Moon at every full moon. If, further, the Moon and Earth were perfect spheres and were revolving in perfect circles, all eclipses of the Sun would be exactly alike, and similarly those

of the Moon. As a matter of fact, none of these conditions is realized, and no two eclipses are quite alike.

The Moon's orbit is tilted at an angle of about 5° to that of the Earth, hence it generally happens that the shadow of the Moon at new moon passes above or below the Earth, and that of the Earth at full moon above or below the Moon. It is only when the Sun at new, or full moon, is near one of the lunar nodes—the name we give to the two points where the two orbits apparently intersect—that an eclipse can occur. An eclipse of the Sun *must* happen when the Sun at time of new moon is within 15⅓° of the node, and *may* happen, under special conditions, when it is as far as 18½° from the node. The limits for eclipses of the Moon are somewhat smaller. Now since the Sun appears to make the circuit of the heavens once each year, it travels less than 30° in a lunar month. Hence at least one new moon must occur while the Sun is still within 15⅓° of the node on one side or the other, and six lunations later the same thing must happen at the other node. Therefore there must be at least two eclipses of the Sun each year. Because the limits for an eclipse of the Moon are smaller, it occasionally happens that a year will pass without any lunar eclipse.

Suppose a total eclipse of the Moon to take place very early in the year, as happened this year, on last Sunday night (January 7). The Moon on this occasion was a little west of its descending node, and the Sun near the opposite or ascending node. Two weeks later, at new moon on Monday, January 22, the Moon has overtaken the Sun at a point east of the descending node but within the eclipse limit and a partial eclipse of the Sun results. Five new moons after this the Sun is west of the descending node and within the eclipse limits, giving another partial solar eclipse on June 18-19; two weeks later, on July 4, it is close to this node and the Moon, at full, is near the ascending node, and the result is another total eclipse of the Moon; still two weeks later, at new moon on July 18, the Moon has overtaken the Sun again just before it reaches the eclipse limit east of the descending node, and a very small partial solar eclipse takes place,—three eclipses within a month's time. Finally, on December 13,

Sun and Moon will be in conjunction so near the ascending node that an annular eclipse of the Sun will result. Two weeks later, on December 27, comes the last eclipse of the year, a total eclipse of the Moon—seven eclipses within the year. This, as has been said, is the maximum number, but it occasionally happens that five out of the seven are eclipses of the Sun, and only two of the Moon. The last year with five solar eclipses was 1823 and the next one will be 1935.

I have mentioned partial, total and annular eclipses of the Sun. A partial eclipse is, of course, one in which only part of the Sun's disk is covered by that of the Moon and needs no comment except that every solar eclipse is a partial one for some stations on the Earth. When at eclipse time the line joining the centers of the Sun and Moon passes thru any part of the Earth also, which happens when conjunction takes place within 10° of the node, the eclipse is central. If the Moon's shadow reaches the Earth, it is total, but if the shadow cannot reach the Earth the Moon's disk will be a little smaller than that of the Sun, and a narrow rim or annulus of sunlight surrounds it when it is projected on the Sun's disk.

The actual length of the Moon's shadow and the distance of the Moon from the Earth are continually varying because the orbits of the Earth and Moon are ellipses, not circles. The following table gives, in round numbers, the average, the greatest and the least values at time of new moon:

Distance from Moon to Earth's Surface	Length of Moon's Shadow	Difference
Average 235,000 miles	Average 232,000 miles	— 3,000 miles
Greatest 249,000 miles	Shortest 228,000 miles	—21,000 miles
Least 218,000 miles	Longest 236,000 miles	+18,000 miles

It follows that the Moon's shadow cannot always reach the Earth's surface, even at the time of a central eclipse, and that, when it does, the cross-section of the shadow cone where it intersects the surface may vary from a mere point to a circle about 168 miles in diameter. Some central eclipses, therefore, are annular, not total, and a total eclipse may be as brief as a fraction of a second or may last nearly eight minutes. Eclipses lasting as long as six minutes are the exception,

however, and the majority last only about two or three minutes.

Another point should be noticed while we are discussing the mechanism of eclipses. The Moon revolves about the Earth from west to east, hence the Moon's shadow at the time of a total eclipse always touches the Earth first at a point where the Sun is just rising, sweeps on eastwardly and leaves the Earth at a point where the Sun is just setting. Meanwhile the Earth itself is turning on its axis from west to east, thus shortening the path along which the shadow travels to about 120° degrees of longitude. Further, the Earth rotates on an axis perpendicular to the equator and the angle between the planes of the equator and the ecliptic is about 23½°. Hence, since the plane of the Moon's orbit makes an angle of 5° with that of the ecliptic, we see that the Moon at the node is moving sometimes at an angle of more than 28° to the equator, sometimes at one only a little over 18°, and this motion will be toward the north at one node and toward the south at the other. The shadow path on the Earth's surface at eclipse time is therefore a curve tending in a general northeasterly or southeasterly direction, the actual figure depending upon the angle between the Moon's orbit and the equator, and the latitude in which the eclipse occurs.

Any given total eclipse is visible only from stations in the comparatively narrow shadow path—ordinarily less than 100 miles wide—and in general this path crosses any given spot on the Earth's surface only at long intervals. For example, the last total eclipse visible from points in the British Islands occurred in 1724, the next one will take place in 1927. The area within which the eclipse is visible as partial is, of course, much wider, extending indeed several thousand miles on either side of the shadow track.

I have said that the ancients had discovered that an eclipse returns after a period of about eighteen years, a period to which they had given the name *Saros*. In one sense every eclipse is the return of its predecessor, but in another sense the statement just made is appropriate and the *Saros* is a cycle of considerable interest.

The Moon makes the circuit from new moon back to new in what we call our ordinary month, 29.53059 days, but it requires only 27.21222 days—a *draconic* month—to pass from node around to the same node again because the node points are constantly retrograding, slipping westward along the ecliptic, an effect due to what we call perturbing forces that we cannot stop to discuss tonight. For the same reason—this retrogression of the nodes—the Sun passes from a node around to the same node in 346.6201 days. Now let us multiply the first period by 223, the second by 242, the third by 19. We shall have, with sufficient accuracy for our purpose, 6585.32, 6585.35 and 6585.78 days respectively, and these values amount to eighteen years, eleven days (ten days if five leap years are included) and the three fractions given. After this interval, which is known as the *Saros*, the three bodies will again stand almost precisely in the same relation to each other, and if an eclipse takes place at a given date, one *Saros* later another will occur under almost the same conditions. Almost, not quite. Because of those three fractions of a day, the Sun and Moon will be a little farther west with respect to the node at the second eclipse, causing slight changes in the direction and length of the shadow, and the Earth will have turned nearly one-third way farther round on its axis, causing the center of the second eclipse to fall correspondingly farther west on its surface. This second eclipse we consider as a "return" of the earlier one, for tho many others have taken place between the two, the positions of Sun and Moon with respect to the node and hence the circumstances of these eclipses were quite different.

To see how this cycle may be used in making approximate forecasts of eclipses, let us compare the eclipses which occurred one *Saros* ago with those which are taking place in the present year:

(1) Total eclipse of Moon,	1898, December 27.	1917, January 7.
(Duration of totality,	1^h29^m	1^h28^m)
(2) Partial eclipse of Sun,	1899, January 11.	1917, January 22.
(Magnitude of eclipse,	0.715	0.725)
(3) Partial eclipse of Sun,	1899, June 7.	1917, June 18-19.
(Magnitude of eclipse,	0.608	0.473)

(4)	Total eclipse of Moon,	1899, June 22-23.	1917, July 4.
	(Duration of totality,	$1^h1^m.5$	$1^h1^m.5$)
(5)	Partial eclipse of Sun,	. . . . .	1917, July 18.
			(Magnitude, 0.086)
(6)	Annular eclipse of Sun,	1899, December 2.	1917, December 13.
	(Center of each eclipse track near the South Pole.)		
(7)	Eclipse of Moon,	1899, December 16.	1917, December 27.
	(Almost total in 1899, magnitude = 0.996; just total in 1917, magnitude = 1.011, duration of totality = $16^m.5$.)		

Each lunar eclipse of the earlier period, it is seen, is repeated this year, the date falling eleven days later, the duration of totality being about the same. The three solar eclipses of the earlier year are followed this year, eleven days later in the year, by eclipses resembling them closely, the point of greatest eclipse, however, falling this year about 120° of longitude farther west. In addition, a new cycle begins this year with the small partial eclipse of the Sun on July 18.

Let us illustrate the recurrence of a single eclipse at *Saros* intervals by considering the cycle to which the eclipse of June 8, 1918, belongs. Like all eclipse cycles this one began as a very slight partial eclipse, when the Sun was at the limit of distance *east* of the Moon's node at the time of new moon. Since, for this family of eclipses the new moon was near the ascending node—the point where its orbit crosses the ecliptic from south to north, the penumbra brushed the Earth near the South Pole at this first eclipse—on March 10, 1179. Eighteen years later, on March 20, 1197, the Sun was a little nearer the node at new moon, and the Moon's disk cut off a little more of the Sun's light. This continued after every *Saros* until June 4, 1323, when the eclipse became central and annular for a short track near the Earth's South Pole. . Annular eclipses continued after each succeeding *Saros,* their paths falling ever farther north, until April 14, 1828. By this time the Sun, at new moon, had passed the node, and at the same time the Moon was nearer the Earth and hence the tip of the actual shadow cone touched the Earth at the middle of the eclipse time at a station in East Africa, 18° north of the equator, completely hiding the Sun

there for a few seconds. The conditions at the next return were similar, the eclipse in April 25, 1846, being annular along the eclipse track except just east of Cuba, in 25° north latitude, where it was total. The following returns, May 6, 1864, May 17, 1882, May 28, 1900, were total, the shadow paths spiralling ever northward. The shadow cone on June 8, 1918, will touch the Earth at sunrise in the Pacific Ocean in 130° east longitude and 26° north latitude, at noon will cross a point in the Pacific at 152° west longitude and 51° north latitude, will enter the United States in southwestern Washington at about 2^h 55^m P. S. T., sweep a path across the country toward the southeast, tapering in width from a little over seventy miles in Washington to less than forty-five miles in Florida, and end at sunset, in the Atlantic east of Cuba, in west longitude 75°, north latitude 25°.

At subsequent returns it will spiral ever farther north, remaining total until the return of August 23, 2044. Then for more than two hundred years it will recur as a partial eclipse, disappearing at length above the North Pole when the Sun at new moon has passed beyond the eclipse limit west of the node.

The actual calculation of an eclipse path and the other attending circumstances, such, for example, as the precise time and duration of totality at a given station within the path, are far too technical matters to be dealt with tonight. Suffice it to say that all this can be calculated with such accuracy that we might easily select now a station for the eclipse, say of August 23, 2044, and set up our telescopes there with the full assurance that the eclipse will occur within a few seconds of the predicted time and that our telescopes will need but very slight adjustments by the observers of that distant day. Whether they would succeed in making the observations planned is another matter. Perhaps by that time our successors will have learned how to control the Earth's atmosphere so as to insure a clear sky at the critical moments. At present we cannot do this, and therefore the intending observer, in selecting a station for his observations, carefully studies all the meteorological data available, and, when the path of totality makes choice of

stations possible, gives the meteorological factor almost the highest weight. Of course, he desires a position where the eclipse will be of maximum duration, for at best it is all too short, but if weather conditions there are highly unfavorable, and are far more promising at a point where the eclipse time is shorter, the latter will be preferred. Often it happens that the shadow path lies mainly across the ocean, touching land only at the edges of the continents near sunrise and sunset, and perhaps crossing an island or two. It may easily happen that at every possible station at such an eclipse the chances for clouds are so great that no observer will care to risk the time and expense an expedition thither would involve.

The great role the Earth's atmosphere plays in astronomical observations is often lost sight of by laymen. For example, our eclipse observers returning from the eclipse of May 28, 1900, in Georgia, recounted with glee the skepticism of a leading citizen of a small town there who had from the first been doubtful of their ability to foretell the occurrence of the eclipse. When he heard their anxious discussions as to the probabilities of cloudiness at the important time, his doubt was deepened to conviction. "These young men try to tell me they know the Sun is going to be eclipsed and they can't even tell me if the sky is going to be clear!"

Better-informed people may well ask, since the duration of an eclipse is so short and the chances of observing it are at best uncertain, why astronomers should devote weeks and months of time in preparations, and travel sometimes half around the world to watch the phenomenon. Let me answer by tracing in a summary way the development of our knowledge of the Sun during the last eighty years. It is not necessary to go back farther, for, broadly speaking, we may say that little more was really known about the Sun in 1840 than had been discovered by Galileo and his contemporaries and immediate successors in the early days of the telescope two centuries before.

The Sun was an enormous globe whose composition and physical condition were unknown. From its intensely hot surface, the photosphere, light and heat were radiated. From time to time spots appeared on this surface and from their

study it was known that they were confined to two broad zones, one on either side of the Sun's equator, that they were often surrounded by areas of extreme brightness — the faculæ—and that the Sun turned on its axis once in twenty-five or twenty-six days. Total eclipses of the Sun had been observed when the shadow paths were conveniently placed, but principally to note the precise times of contact of the disks of the Sun and Moon for the purpose of improving the lunar and solar tables. The corona was noted of course—it could hardly have escaped the notice of even the earliest witnesses of an eclipse—and there are occasional references to rosy or scarlet or flame-colored appearances close to the Moon's disk during totality, but these features attracted strangely little scientific attention.

One discovery of capital importance had been made, tho not at an eclipse. Fraunhofer, in 1815, had found that the solar spectrum, produced by passing a beam of sunlight thru a narrow aperture or slit and then thru a prism, is crossed by a series of fine dark lines which always fall in the same positions with respect to the colors of the spectrum, but their significance was unknown.

The real impetus to advance in solar studies, we may say, was given by the eclipse of July 8, 1842. The Moon's shadow on that occasion swept across Europe and many prominent astronomers occupied stations on the shadow path. The corona was strikingly beautiful, and, fortunately, at least three large brilliant flame-colored protuberances—now known as prominences—were visible. What caused them, and what was the corona? These questions were now for the first time generally discussed, and it was soon apparent that astronomers were divided in their opinions. Some held that they were solar appendages, others that they belonged to the Moon, while a third group argued that they were not objective realities at all, but were optical phenomena produced by diffraction of the Sun's light at the irregular mountainous circumference of the Moon's disk. Further eclipses were now looked forward to with interest, and in the next thirty years a number occurred that were well observed. Move-

over, new instruments were made available to study their phenomena.

Photographic processes had been so far perfected that they could be systematically applied at the Spanish eclipse of July 18, 1860. In the preceding year, 1859, Kirchhoff had shown that the Fraunhofer lines could be explained on the assumption that the light from the Sun's photosphere passes thru a gaseous layer or envelope which, while intensely hot, is cooler than the photosphere itself. This layer of gases would "absorb" light of precisely the wave-lengths it was itself capable of emitting. Hence the positions of the lines not only tell us the composition of the gaseous layer, but when the photospheric light is cut off, as for example, by the interposition of the Moon's disk at the time of total eclipse, the lines themselves should flash out as bright lines. Precisely this phenomenon was observed by C. A. Young at the eclipse of December 22, 1870. He was watching the Fraunhofer lines in his spectroscope as the Sun gradually disappeared behind the Moon's advancing disk, and just as the last rays of photospheric light were cut off he saw them suddenly flash out as bright lines. In a second or two they were gone—covered by the advancing Moon. But the existence of the "reversing layer" above the photosphere had been established by actual observation.

Meanwhile the photographic camera and spectroscope had definitely proved (1) that the prominences and the inner corona were real and belonged to the Sun, for the Moon's disk clearly traversed them in its motion; (2) that the prominences were vast masses of luminous gases—hydrogen, helium, calcium—rising from a continuous layer (the chromosphere) of such materials surrounding the Sun; (3) that the corona was at least partly gaseous—for its spectrum showed a bright line of green light due to some element not even yet identified but called "coronium"—but that it shone also in part by reflected sunlight, for Fraunhofer lines were present, and the light was partly polarized.

If an astronomer had been fortunate enough to be able to observe successfully every total eclipse that has occurred from 1860 to the present year, he would, in all, have had

less than two hours' time of actual observation, yet it is clear that this short space of time has advanced our knowledge of the Sun beyond the dreams of astronomers a century ago.*

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Total eclipses of the Sun must still play their part in advancing our knowledge of the forces that are in action upon the Sun, and of the relations between corona, prominences and sun-spots, tho we may not now hope to discover new enveloping layers. The corona has been seen and photographed only at the time of total eclipse, in spite of strenuous efforts made by the most skilful observers, and it now seems that the attempt to study it at other times is hopeless. For Abbot, using that extremely delicate electric thermometer which we call the bolometer, an instrument that can reveal the variation of 0°.000,000,1 C. of heat radiation, has shown that the sky radiation even 20° from the Sun is more than ten times greater than that of even the bright inner corona, and that the latter is therefore beyond the reach of any existing form of instrument except at times of eclipse.

Eclipses, too, afford the best if not the only opportunity to study other questions not strictly related to the constitution of the Sun; for example, whether or not there exists a planet of any notable size within the orbit of *Mercury,* and whether the force of gravity has the power to deflect light, as postulated by the modern theory of relativity. The former question was prominent in the plans of recent eclipses but has now been quite definitely settled in the negative mainly by the observations by Lick Observatory expeditions. The latter will certainly hold a prominent place in the program for the eclipse of June 8, 1918.

Thanks to the liberality of generous friends—the late Colonel Fred Crocker, Mrs. Phœbe A. Hearst, and, particularly, Mr. W. H. Crocker, all members of our Society—the Lick Observatory has from the first been able to take a prominent part in solar eclipse work. Since the California eclipse of January 1, 1889, of which I spoke at the beginning, expeditions have been sent out at the expense of one or the

* A general description of the Sun as we know it was given at this point in the spoken lecture.

other of these three friends of the observatory to eclipses in nine different years, and in only two of these years—1896 and 1914—did clouds prevent success. Other eclipses have occurred within this period, but the prospects of good weather were too poor to justify an expedition. Doubtless a party will be sent from the Lick Observatory in June, 1918, to a suitable station—perhaps in southern Idaho or eastern Oregon, where weather conditions are unusually promising and where the total phase on June 8 will last a little less than two minutes.*

The American Astronomical Society has already appointed a special eclipse committee to make general plans for observing the eclipse of June 8, 1918, and it is quite certain that many American observatories will send out parties at that time. The shadow enters the United States on the coast of Washington in latitude $+46° 50'$ at $2^h 55^m$ P. S. T., and moving rapidly southeastward leaves the land on the coast of Florida shortly before sunset. But we must remember that sunset in Florida comes when the Sun in our longitude is still three hours or more above the horizon. The Moon's shadow sweeps across the country from the Washington coast to that of Florida in just forty-seven minutes. A number of cities lie close to the central line of the shadow path, among them Baker City (Oregon), Hailey and Montpelier (Idaho), Central City and Denver (Colorado), Jackson (Mississippi), and Orlando (Florida). Denver is the site of the Chamberlin Observatory, which possesses a twenty-inch refractor adapted for photographic as well as visual observations. Professor Howe and his associates can observe the eclipse, therefore, with their regular observatory instruments and need send out no expedition. The most favorable locations for this eclipse are unquestionably on the line from eastern Oregon thru Idaho and Colorado: the Sun during totality will be higher in the sky here than farther east, the eclipse will last longer, and the meteorological conditions will be most promising.

* The experiences of the Lick Observatory-Crocker Expedition to Flint Island to observe the total eclipse of January 3, 1908, were related to illustrate eclipse work. Dr. Campbell's account of this expedition was printed in these *Publications*, Volume **20**, p. 63, 1908.

The eclipse committee has made no report as yet, but it is safe to forecast the general nature of the observations that will be made and their purpose. The corona will certainly be the principal object of study. Large-scale and small-scale photographs will be taken, some with short exposures for the brighter portions, some with long exposures for the fainter regions. Intercomparison of these photographs will enable us to build up a true picture of the actual corona. Direct photographs, and others taken with the spectroheliograph at observatories like the one on Mount Wilson, on the day of the eclipse and on the preceding and following days, will record the number and location of the sun-spots, faculæ and prominences, and the distribution of hydrogen, calcium and other gases in the upper regions of the Sun; and the comparative study of these photographs with those taken by the eclipse expeditions will, it is to be hoped, throw new light upon the constitution of the corona and upon its relations to the other solar envelopes.

Spectrographic observations will play an important part and spectrographs of several different types will be used (1) to record the general coronal spectrum and the distribution of coronal light in the spectrum; (2) to determine the precise wave-lengths of the coronal lines, especially the green line of *coronium*, and to record the distribution of this gas at least in the inner corona; (3) to photograph the violet and ultra-violet coronal spectrum; and (4) to photograph the "flash spectrum."

Spectroheliographs may possibly be used to photograph the chromosphere, prominences and inner corona; bolometers will measure the intensity of the radiation of the corona at different distances from the Moon's limb, and special magnetic measures and meteorological observations will undoubtedly be made. Fairly successful "moving-picture" records have been secured at one or two recent eclipses. Several such records ought to be made at different stations on June 8, 1918.

Two minutes is not a very long time, but a single expedition, well planned and thoroly prepared to utilize every second to the utmost can secure most valuable material. A number

of parties working in coöperation, according to pre-arranged plans, should secure data that will mark a long step forward in our knowledge of the Sun.

As to observations not directly relating to the Sun, it is probable that search for an intramercurial planet will not figure, except incidentally, but telescopes of the same type as those used in this search at recent eclipses—that is, batteries of four telescopes of about eleven feet focal length so mounted upon a single polar axis as to give simultaneous photographs of the entire region about the Sun—will undoubtedly be used to test the relativity theory now so prominent in theoretical physics. It is a consequence of that theory that a beam of light passing thru a gravitational field should be deflected from its course just as a material particle traveling with the velocity of light would be. If, then, a star is so situated that its light in falling on the Earth passes close to the limb of the Sun, it should be bent in toward the Sun by about $0''.9$. If it passes $20'$ from the Sun, the deflection is less than half as great. If two stars are placed on opposite sides of the Sun, their light will be deflected in opposite directions and the effect will thus be doubled. Now stars so near the Sun, even if bright, can be photographed only at the time of eclipse. Hence the plan is to take plates at eclipse time, measure the distance between star images suitably placed upon them, and compare the result with the distance between the same stars photographed with the same telescopes at an earlier season when the Sun is out of the way. If the attraction of the Sun has affected the direction of the light beam, the distance on the eclipse plates will be a little greater—the amount depending on the positions of the stars—than that on the other plates. The theory of relativity, while far too technical to be discussed here, is of such importance to our fundamental physical concepts that these tests, the only quantitative observational tests that can be made of it at present, will be of the greatest interest.

January 8, 1917.